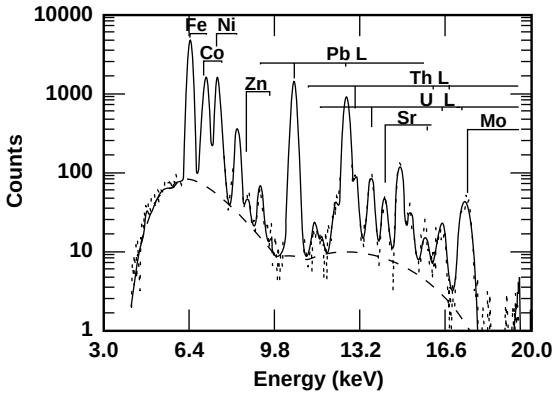
Particle-Induced X-Ray Emission (PIXE)

A trace-element detector 100 times more sensitive than electron micro-analysis systems

PIXE is an analytical technique capable of trace element detection sensitivity of a few parts per million. When ions pass through matter, they interact with the electrons in the atoms and occasionally a vacancy is produced by an excited electron. When this occurs in an inner shell, the vacancy is filled by an electron from an outer shell, and an x-ray photon of characteristic energy is emitted. By measuring the energy, we can determine the atomic number and the amount of that element present can be extracted from the area under the x-ray peak. For identification and quantification of trace elements, PIXE is 100 times more sensitive than electron micro-analysis systems. The Ion Micro-Analysis Group (IMAG) has two beamlines used for bulk and micro-PIXE applications at LLNL's Multi-User Tandem Laboratory (MTL). IMAG is a collaboration of researchers at Lawrence Livermore and Sandia national laboratories.



Characteristic ray spectrum obtained by scanning a 500x500 micron area of a particulate filter using a 10 micron 3 MeV proton beam. The elemental constituents are labeled and the solid line give the best fit to the data (dots) from which concentrations can be obtained.

PIXE microanalysis

MTL uses a FN tandem accelerator to provide ions for PIXE analysis. Usually 2-4 MeV protons are used, but heavier ions (such as Li, C and O) have also been used (for increased sensitivity). The ions are focused using quadruple lenses to a spot size of approximately 1 micron for protons (about 10 microns for 12C). The ion beam can be rastered over the sample to provide two-dimensional spatial distributions of the elements present. Thus, PIXE not only gives average concentrations, it can be used for studying how the elemental concentrations vary over the surface on a sample. By using sample rotation in addition to beam rastering, three dimensional elemental images of a sample can be obtained (a PIXE tomograph).

APPLICATIONS

- *Trace element detection in biological samples*
- *Environmental sample analysis*
- *Particulate composition and distributions*
- *Impurity determinations in radiation detector materials*
- *Spatial distribution of elements in samples*

Advantages of PIXE

Perhaps the main reason for PIXE's highly sensitive trace element detection is the reduced bremsstrahlung background compared to the electron microprobe. The increased signal-to-noise ratio allows trace impurity detection down to 1 ppm or less—up to two orders of magnitude better than electron microprobes. The bremsstrahlung produced in PIXE is a secondary effect, not the primary background contributor as in electron microprobes. The electron microprobe does offer very good spatial resolution, but this can only be maintained for very thin specimens, which are not as well suited for elemental analysis because of the extremely small mass traversed. For thicker samples, the spatial resolution of the electron microprobe deteriorates because of electron multiple scattering. Protons, on the other hand, are very little affected by scattering. Detection limits on the order of 10^{-15} to 10^{-16} g can be achieved. In general, PIXE can be characterized as a quantitative, accurate, and highly sensitive method for multi-elemental analysis of materials. For trace element detection in biological tissue, PIXE is the preferred method.

Availability: PIXE technology is available now.

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